

WHAT IS CLAIMED IS:

1. An indirect measurement system for determining an estimated
2 value of a parameter of interest of an object, comprising:
a sensor that produces a raw measurement that is indirectly
4 representative of said parameter of interest of said object;
a correction function that corrects said raw measurement to a
6 corrected measurement to minimize measurement differences between said
indirect measurement system and a reference indirect measurement system;
8 a reference map function that estimates said estimated value of said
parameter of interest of said object based on said corrected measurement;
10 and
a correction function fitting procedure that fits said correction function
12 based on reference values for one or more calibration samples measured on
or simulated for said reference indirect measurement system and
14 corresponding values measured on said indirect measurement system.

2. An indirect measurement system in accordance with claim 1,
2 wherein:
said correction function comprises one of a low-order polynomial
4 function and a parametric function characterized by a small number of
parameters.

3. An indirect measurement system in accordance with claim 1,
2 comprising:
a reference map function fitting procedure that fits said reference map
4 function based on known values of the parameter of interest associated with
each of one or more reference calibration samples and corresponding
6 reference values for said one or more reference calibration samples
measured on or simulated for said reference indirect measurement system.

4. An indirect measurement system in accordance with claim 1,
2 comprising:

4 a classification function that classifies said object into one of a
plurality of classes based on said estimated value of said parameter of
interest.

2 5. A system for calibrating a first indirect measurement system with
respect to a second indirect measurement system, said first indirect
measurement system comprising a sensor that produces a raw
4 measurement that is indirectly representative of a parameter of interest of an
object sensed by said sensor, a correction function that corrects said raw
6 measurement to a corrected measurement to minimize measurement
differences between said first indirect measurement system and said second
8 indirect measurement system, and a reference map function that estimates
an estimated value of said parameter of interest of said object based on said
10 corrected measurement, said system comprising:

a correction function fitting procedure that fits said correction function
12 based on reference values for one or more calibration samples measured on
or simulated for said second indirect measurement system and
14 corresponding values measured on said first indirect measurement system.

2 6. A system in accordance with claim 5, wherein:
said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

2 7. A system in accordance with claim 5, wherein:
said correction function fitting procedure permits updating said
correction function without updating said reference map function.

2 8. A system in accordance with claim 5, comprising:
a reference map function fitting procedure that fits said reference map
function based on known values of the parameter of interest associated with
4 each of one or more reference calibration samples and corresponding
reference values for said one or more reference calibration samples
6 measured on or simulated for said second indirect measurement system.

9. A method for calibrating a first indirect measurement system with
2 respect to a second indirect measurement system, said first indirect
measurement system comprising a sensor that produces a raw
4 measurement that is indirectly representative of a parameter of interest of an
object sensed by said sensor, a correction function that corrects said raw
6 measurement to a corrected measurement to minimize measurement
differences between said first indirect measurement system and said second
8 indirect measurement system, and a reference map function that estimates
an estimated value of said parameter of interest of said object based on said
10 corrected measurement, said method comprising the steps of:
obtaining measurement values of one or more calibration samples
12 measured on said first indirect measurement system; and
fitting said correction function based on said obtained measurement
14 values of said one or more calibration samples and corresponding known
reference values measured on or simulated for said second indirect
16 measurement system.

10. A method in accordance with claim 9, wherein:
2 said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

11. A method in accordance with claim 9, further comprising the
2 steps of:
re-obtaining measurement values of said one or more calibration
4 samples measured on said first indirect measurement system; and
re-fitting said correction function based on said re-obtained
6 measurement values of said one or more calibration samples and
corresponding known reference values measured on or simulated for said
8 second indirect measurement system.

12. A method in accordance with claim 9, further comprising the
2 steps of:

obtaining reference values of one or more reference calibration
4 samples measured on or simulated for said second indirect measurement
system; and
6 fitting said reference map function based on said obtained reference
values of said one or more reference calibration samples to corresponding
8 known values of the parameter of interest associated with each of said one
or more reference calibration samples.

13. A method in accordance with claim 12, further comprising:
2 updating said correction function without updating said reference map
function.

14. A computer readable storage medium tangibly embodying
2 program instructions implementing a method for calibrating a first indirect
measurement system with respect to a second indirect measurement
4 system, said first indirect measurement system comprising a sensor that
produces a raw measurement that is indirectly representative of a parameter
6 of interest of an object sensed by said sensor, a correction function that
corrects said raw measurement to a corrected measurement to minimize
8 measurement differences between said first indirect measurement system
and said second indirect measurement system, and a reference map
10 function that estimates an estimated value of said parameter of interest of
said object based on said corrected measurement, the method comprising
12 the steps of:

obtaining measurement values of one or more calibration samples
14 measured on said first indirect measurement system; and
fitting said correction function based on said obtained measurement
16 values of said one or more calibration samples and corresponding known
reference values measured on or simulated for said second indirect
18 measurement system.

15. The computer readable storage medium of claim 14, wherein:

2 said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

16. The computer readable storage medium of claim 14, the method
2 further comprising the steps of:

re-obtaining measurement values of said one or more calibration
4 samples measured on said first indirect measurement system; and
re-fitting said correction function based on said re-obtained
6 measurement values of said one or more calibration samples and
corresponding known reference values measured on or simulated for said
8 second indirect measurement system.

17. The computer readable storage medium of claim 14, the method
2 further comprising the steps of:

obtaining reference values of one or more reference calibration
4 samples measured on or simulated for said second indirect measurement
system; and
6 fitting said reference map function based on said obtained reference
values of said one or more reference calibration samples to corresponding
8 known values of the parameter of interest associated with each of said one
or more reference calibration samples.

18. The computer readable storage medium of claim 17, the method
2 further comprising the step of:

updating said correction function without updating said reference map
4 function.

19. An automated inspection system, comprising:

2 an imaging system utilizing a source of penetrating radiation and one
or more sensors to detect said penetrating radiation reflected by, scattered
4 by, transmitted through, or emitted from an object and to generate an image
of said object from which is derived one or more features of said object that
6 are representative of a parameter of interest of said object;

8 a correction function that corrects said one or more features derived
from said image of said object to one or more corresponding corrected
features to minimize differences between said automated inspection system
10 and a reference automated inspection system; and

a reference map function that estimates an estimated value of said
12 parameter of interest of said object based on said one or more
corresponding corrected features; and

14 a correction function fitting procedure that fits said correction function
based on one or more features derived from one or more images of one or
16 more calibration samples imaged on said automated inspection system and
corresponding reference features derived from one or more reference
18 images imaged on said reference automated inspection system.

20. An automated inspection system in accordance with claim 19,
2 wherein:

said correction function comprises one of a low-order polynomial
4 function and a parametric function characterized by a small number of
parameters.

21. An indirect measurement system in accordance with claim 19,
2 comprising:

a classification function that classifies said object into one of a
4 plurality of classes based on said estimated value of said parameter of
interest.

22. An automated inspection system in accordance with claim 19,
2 wherein:

said source of penetrating radiation comprises x-rays; and
4 said image of said object comprises a gray level value representing
detection of said x-rays.

23. An automated inspection system in accordance with claim 19,
2 wherein:

4 said object comprises a solder joint of a printed circuit board and said
parameter of interest is a solder thickness of said solder joint or a portion
thereof.

2 24. A system for calibrating a first automated inspection system with
respect to a second automated inspection system, said first automated
inspection system comprising an imaging system utilizing a source of
4 penetrating radiation and one or more sensors to detect said penetrating
radiation reflected by, scattered by, transmitted through, or emitted from an
6 object and to generate an image of said object from which is derived one or
more features of said object that are representative of a parameter of
8 interest of said object, a correction function that corrects said one or more
features derived from said image of said object to one or more
10 corresponding corrected features to minimize differences between said first
automated inspection system and said second automated inspection system,
12 and a reference map function that estimates an estimated value of said
parameter of interest of said object based on said one or more
14 corresponding corrected features, said system comprising:

16 a correction function fitting procedure that fits said correction function
based on one or more features derived from one or more images of one or
more calibration samples imaged on said first automated inspection system
18 and corresponding reference features derived from one or more reference
images imaged on said second automated inspection system.

2 25. A system in accordance with claim 24, wherein:
said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

2 26. A system in accordance with claim 24, wherein:
said correction function fitting procedure permits updating said
correction function without updating said reference map function.

27. A system in accordance with claim 24, comprising:

2 a reference map function fitting procedure that fits said reference map
function based on known values of the parameter of interest associated with
4 each of one or more reference calibration samples and corresponding
reference features derived from one or more images of said one or more
6 reference calibration samples imaged on said second automated inspection
system.

28. A system in accordance with claim 24, wherein:
2 said source of penetrating radiation comprises x-rays; and
said image of said object comprises a gray level value representing
4 detection of said x-rays.

29. A system in accordance with claim 24, wherein:
2 said object comprises a solder joint of a printed circuit board and said
parameter of interest is a solder thickness of said solder joint or a portion
4 thereof.

30. A method for calibrating a first automated inspection system with
2 respect to a second automated inspection system, said first automated
inspection system comprising an imaging system utilizing a source of
4 penetrating radiation and one or more sensors to detect said penetrating
radiation reflected by, scattered by, transmitted through, or emitted from an
6 object and to generate an image of said object from which is derived one or
more features of said object that are representative of a parameter of
8 interest of said object, a correction function that corrects said one or more
features derived from said image of said object to one or more
10 corresponding corrected features to minimize differences between said first
automated inspection system and said second automated inspection system,
12 and a reference map function that estimates an estimated value of said
parameter of interest of said object based on said one or more
14 corresponding corrected features, said method comprising:
obtaining one or more features derived from one or more images of
16 one or more calibration samples imaged on said first automated inspection
system; and

18 fitting said correction function based on said one or more features
derived from said one or more images of said one or more calibration
20 samples and corresponding reference features derived from one or more
reference images imaged on said second automated inspection system.

31. A method in accordance with claim 30, wherein:
2 said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

32. A method in accordance with claim 30, comprising:
2 re-obtaining one or more features derived from one or more images of
said one or more calibration samples imaged on said first automated
4 inspection system; and
re-fitting said re-obtained one or more features derived from said one
6 or more images of said one or more calibration samples and corresponding
reference features derived from one or more reference images imaged on or
8 simulated for said second automated inspection system.

33. A method in accordance with claim 30, further comprising the
2 steps of:
obtaining one or more reference features derived from one or more
4 images of one or more reference calibration samples imaged on said second
automated inspection system; and
6 fitting said reference map function based on said obtained one or
more reference features derived from said one or more images of said one
8 or more reference calibration samples and corresponding known values of
the parameter of interest associated with each of said one or more reference
10 calibration samples.

34. A method in accordance with claim 33, further comprising the
2 step of updating said correction function without updating said reference
map function.

35. A method in accordance with claim 30, wherein:
2 said source of penetrating radiation comprises x-rays; and
 said one or more images or features derived therefrom comprises a
4 gray level value reflecting detection of said x-rays penetrating said object.

36. A method in accordance with claim 30, wherein:
2 said object comprises a solder joint of a printed circuit board and said
 parameter of interest is a solder thickness of said solder joint or a portion
4 thereof.

37. A computer readable storage medium tangibly embodying
2 program instructions implementing a method for calibrating a first automated
 inspection system with respect to a second automated inspection system,
4 said first automated inspection system comprising an imaging system
 utilizing a source of penetrating radiation and one or more sensors to detect
6 said penetrating radiation reflected by, scattered by, transmitted through, or
 emitted from an object and to generate an image of said object from which is
8 derived one or more features of said object that are representative of a
 parameter of interest of said object, a correction function that corrects said
10 one or more features derived from said image of said object to one or more
 corresponding corrected features to minimize differences between said first
12 automated inspection system and said second automated inspection system,
 and a reference map function that estimates an estimated value of said
14 parameter of interest of said object based on said one or more
 corresponding corrected features, the method comprising the steps of:
16 obtaining one or more features derived from one or more images of
 one or more calibration samples imaged on said first automated inspection
18 system; and
 fitting said correction function based on said one or more features
20 derived from said one or more images of said one or more calibration
 samples and corresponding reference features derived from one or more
22 reference images imaged on said second automated inspection system.

38. The computer readable storage medium of claim 37, wherein:

2 said correction function comprises one of a low-order polynomial
function and a parametric function characterized by a small number of
4 parameters.

39. The computer readable storage medium of claim 37, the method
2 further comprising:

re-obtaining one or more features derived from one or more images of
4 said one or more calibration samples imaged on said first automated
inspection system; and

6 re-fitting said re-obtained one or more features derived from said one
or more images of said one or more calibration samples and corresponding
8 reference features derived from one or more reference images imaged on or
simulated for said second automated inspection system.

40. The computer readable storage medium of claim 37, the method
2 further comprising:

obtaining one or more reference features derived from one or more
4 images of one or more reference calibration samples imaged on said second
automated inspection system; and

6 fitting said reference map function based on said obtained one or
more reference features derived from said one or more images of said one
8 or more reference calibration samples and corresponding known values of
the parameter of interest associated with each of said one or more reference
10 calibration samples.

41. The computer readable storage medium of claim 40, further
2 comprising the step of:

updating said correction function without updating said reference map
4 function.

42. A method in accordance with claim 37, wherein:

2 said source of penetrating radiation comprises x-rays; and
said one or more images or features derived therefrom comprises a
4 gray level value reflecting detection of said x-rays penetrating said object.

43. A method in accordance with claim 37, wherein:

2 said object comprises a solder joint of a printed circuit board and said
parameter of interest is a solder thickness of said solder joint or a portion

4 thereof.